Threats 3

This chapter summarizes threats to coho salmon. The severity of the decline in the numbers of coho salmon and the number of extirpated populations increases as one moves closer to the historical southern limit of the species' range, suggesting that these environments are less able to support coho salmon populations than in the past. Freshwater habitat loss and degradation have been identified as leading factors in the decline of anadromous salmonids in California, including the coho salmon. Past timber harvest activities, especially road construction, have had deleterious effects on coho salmon habitat. Urbanization and increased diversion of water for agricultural, domestic, and other purposes, and dams that block access to former habitat, have resulted in further reduction of habitat. Water quality in streams historically inhabited by coho salmon has degraded, as evidenced by the number of north- and central-coast streams that have been placed on the list of impaired water bodies, pursuant to §303 of the Clean Water Act (CWA).

3.1 CLIMATIC VARIATION

California experiences wide variation in climatic and hydrologic conditions. Various climatic phenomena including severe storms, drought, seasonal cycles, El Niño and La Niña events, decadal events, and regime shifts can alter the physical, chemical, and biological aquatic environment (Parrish and Tegner 2001). These changes can, in turn, play a major role in the life history, productivity, and persistence of coho salmon populations. Coho salmon evolved with, and have persisted in the face of, extreme variability in habitat conditions caused by these natural phenomena. However, catastrophic conditions combined with low population numbers, habitat fragmentation, impacts of human activities, and habitat degradation or loss can cause an unrecoverable decline of a given population or species (Moyle et al. 1995).

3.1.1 DROUGHT

In California, coho salmon populations exist in many coastal streams where stream closures occur at their mouths when coastal wave action and low summer flows lead to sandbar formation. Coho salmon are able to identify their natal stream by the seepage of fresh water entering the ocean through the bars, but they are unable to enter the streams until fall or winter rains increase flows sufficiently to breach the sand bars. Shapovalov and Taft (1954) found that streams south of San Francisco may not be passable until as late as March. When this happens, a large portion of the run may enter the stream over a short period. Up to 70% of the total returning spawning population may enter the stream from the ocean within a few days (Sandercock 1991). During prolonged droughts, sandbars may never open in a given season. When that happens, spawners are unable to enter those streams (Anderson 1995). Reduced flows can reduce habitat quantity and result in increased water temperature, causing increased heat stress to fish and thermal barriers to migration.

3.1.2 FLOODING

High flows associated with floods can result in complete loss of eggs and alevins as they are scoured from the gravel or buried in sediment (Sandercock 1991; NMFS 1998). Juveniles and smolts can be stranded on the flood plain, washed downstream to poor habitat such as isolated side channels and off-channel pools, or washed out to sea prematurely. Peak flows can induce adults to move into isolated channels and pools or prevent their migration through excessive water velocities.

Streams can be drastically modified by erosion and sedimentation in large flood flows almost to the extent of causing uniformity in the stream bed (Spence et al. 1996). After major floods, streams can take years to recover pre-flood equilibrium conditions. Flooding is generally not as devastating to salmon in morphologically complex streams, because protection is afforded to the fish by the natural in-stream structures such as LWD and boulders, stream channel features such as pools, riffles, and side channels and an established riparian area (Spence et al. 1996).

Flooding does, however, have beneficial effects such as cleaning and scouring of gravels, transporting sediment to the flood plain, moving and rearranging LWD, recharging flood plain aquifers (Spence et al. 1996), allowing salmonids greater access to a wider range of food sources (Pert 1993), and maintaining the active channel.

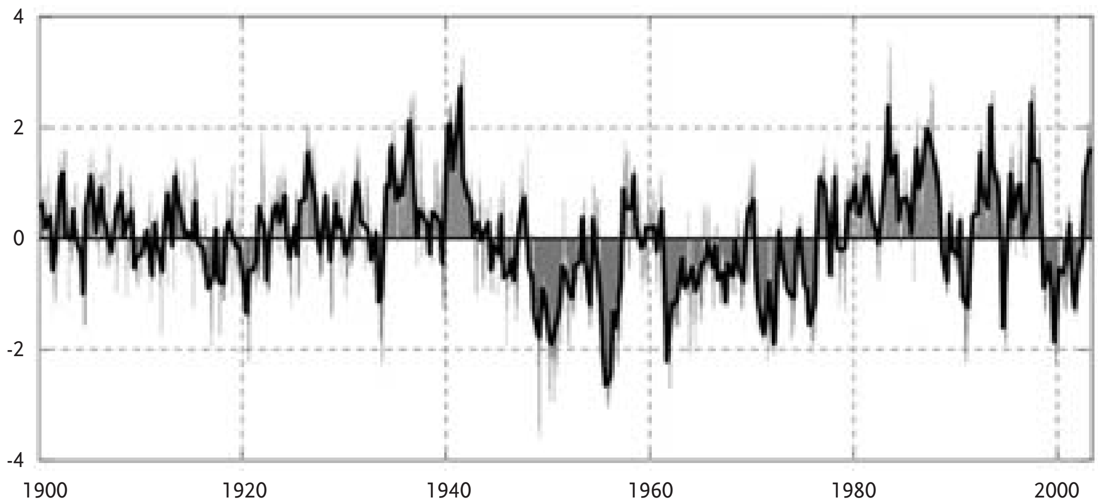
3.1.3 OCEAN CONDITIONS

Changing ocean conditions, extreme climatic conditions, and natural variation in ocean conditions can strongly impact Pacific salmon populations. However, salmon populations have not, until the past century, experienced these conditions in conjunction with the widespread degradation of their spawning, rearing, and overwintering habitat caused by human related activities (Brown et al. 1994; Anderson 1995).

Periodic changes in Pacific currents, winds, and upwelling regimes have had major impacts on the primary and secondary productivity of the northeast Pacific Ocean (Brown et al. 1994; Mantua et al. 1997). These oceanic events, described as El Niño/Southern Oscillation (ENSO) and Pacific interdecadal oscillation (PDO) are associated with declines and increases in ocean survival and decreases and increases in size of coho and Chinook salmon (Johnson 1988; Spence et al. 1996; Tschaplinski 1999; Cole 2000; Ryding and Skalski 1999; Koslow et al. 2002). ENSO events are of relatively short duration (6-18 months) with their primary influence in the tropics and secondary expression in the North Pacific/North American sector. In contrast, PDO events are most visible in the North Pacific and typically cycle over periods of about 50 years; within a PDO cycle there may be short-lived reversals of conditions (Mantua 2003). Figure 3-1 summarizes monthly PDO indices developed by the University of Washington; negative values indicate cool PDO periods that are generally favorable for coho salmon populations in California.

Marine conditions have several ramifications that must be considered in planning for coho salmon recovery and the interpretation of monitoring results. The cyclic nature of marine productivity, as outlined by Lawson (1993), can mask the reproductive decline of a salmonid population. The conceptual model he presents combines the effects of oceanic cycles and freshwater habitat degradation. As the freshwater habitat degrades, the salmon populations do not decline in an immediate and linear fashion. Instead, due to the long-term cycles of productivity in the marine environment, the downward trend in freshwater productivity can be masked by higher escapement due to more favorable oceanic conditions. These trends must be considered when assessing the success of coho salmon recovery efforts.

FIGURE 3-1: Monthly values for the Pacific interdecadal oscillation index: January 1900 to April 2003



SOURCE: http://tao.atmos.washington.edu/pdo/

3.2 DISEASE

Coho salmon are susceptible to an array of bacterial, viral, parasitic, and fungal diseases found in many salmonids of the Pacific Northwest. Symptomatic conditions appear when fish are stressed by high water temperatures, crowding, environmental contaminants, or decreased oxygen supply (Warren 1991). Diseases affect various life stages differently. Diseases and disease agents in California that can cause significant losses in adult salmonids include: bacterial kidney disease *(Renibacterium salmoninarum)*, furunculosis *(Aeromonas salmonicida)*, columnaris *(Flexibacter columnaris)*, pseudomonas infection, aeromonas infection, and ichthyopthirius or "ich" *(Ichthyophthirius multifiliis)* (W. Cox pers. comm.). The diseases that are known to cause significant losses in juvenile salmonids are furunculosis, columnaris, coldwater disease *(Flexibacter psychrophilis)*, pseudomonas, aeromonas, ichthyopthirius, nanophyetes, and ceratomyxosis *(Ceratomyxa shasta)* (William Cox pers. comm.).

The introduction of disease by hatchery fish into wild stocks is an increasing concern, but the degree of risk and seriousness of the problem are little known (Brown et al. 1994).

3.3 PREDATION

Predation occurs during all life stages of the coho salmon and it is accommodated by a healthy population; however it can be detrimental to those populations with low numbers or poor habitat conditions (Anderson 1995).

3.3.1 FRESHWATER PREDATION

Predators in the freshwater environment, such as invertebrates, fish, and birds, reduce the survival rate of eggs and alevins (Sandercock 1991). Some native fishes known to consume coho salmon are: sculpin *(Cottus spp.)*, Sacramento pikeminnow *(Ptychocheilus grandis)*, steelhead rainbow trout *(Oncorhynchus mykiss)*, coastal cutthroat trout *(O. clarki clarki)*, and other coho salmon (Shapovalov and Taft 1954; Sandercock 1991; Anderson 1995). Non-native fishes such as Sacramento pikeminnow *(Ptychocheilus grandis)* introduced to the Eel River, smallmouth bass *(Micropterus dolomieu),* and channel catfish (*Ictalurus punctatus*) can consume significant numbers of juvenile salmon if the conditions are favorable for them (NMFS 1998). Striped bass *(Morone saxatilis)* can also be a significant predator of juvenile salmonids, and has been observed in the Russian River system. However, current information does not indicate that they have had a significant impact on coho salmon populations. Avian predators of juvenile salmonids include dipper *(Cinclus mexicanis),* gulls *(Larus spp.),* double-crested cormorant *(Phalacrocorax auritus),* belted kingfisher *(Megaceryle alcyon),* herons *(Ardea spp.),* common merganser *(Mergus merganser),* and osprey *(Pandion haliaetus)* (Fresh 1997; Sandercock 1991; Spence et al. 1996). Among mammalian predators that can impact salmonid populations, mink *(Mustela vison)* and otter *(Lutra canadensis)* can take significant numbers of the overwintering coho salmon juveniles and migrating smolts, although this is dependent upon conditions favorable to predators and the availability of other prey (Sandercock 1991).

3.3.2 MARINE PREDATION

The relative impacts of marine predation on anadromous salmonids are not well understood, though documentation of predation from certain species is available. NMFS (1998) noted that several studies have indicated that piscivorous predators may control salmonid abundance and survival. Beamish et al. (1992) documented predation of hatchery-reared Chinook and coho salmon by spiny dogfish *(Squalus acanthias)*. Pacific hake *(Merluccius productus)* and pollock *(Theragra chalcogramma)* are known to consume salmon smolts (Holtby et al. 1990). Marine sculpins also consume juvenile salmonids, although salmonids are not a major part of their diet.

There are many known avian predators of juvenile salmonids in the estuarine and marine environments. Some of these include belted kingfisher, gulls, grebes *(Podicipedidae)*; and loons *(Gavia spp.)*, herons, egrets, bitterns *(Ardeidae)*; cormorants *(Phalacrocorax spp.)*, terns (*Sterna* spp.), mergansers *(Mergus spp.)*, pelicans *(Pelecanus spp.)*, auklets, murres, murrelets, guillemots, and puffins *(Alcidae)*; and sooty shearwater *(Puffinus grisens)* (Emmett and Schiewe 1997; NMFS 1998). Bald eagles *(Haliaeetus leucocephalus)* and osprey are predators of adult salmonids (Emmett and Schiewe 1997). It is important to note that these predators are opportunistic feeders, preying upon the most abundant and easiest to catch.

In most cases, salmonids appear to be a minor component of the diet of marine mammals (Scheffer and Sperry 1931; Jameson and Kenyon 1977; Graybill 1981; Brown and Mate 1983; Roffe and Mate 1984; Hanson 1993; Botkin et al. 1995; Goley and Gemmer 2000; Williamson and Hillemeier 2001a, 2001b). The principal food sources of marine mammals include lampreys (Jameson and Kenyon 1977; Roffe and Mate 1984; Hanson 1993), benthic and epibenthic species (Brown and Mate 1983; Hanson 1993), and flatfish (Scheffer and Sperry 1931; Graybill 1981; Hanson 1993; Goley and Gemmer 2000; Williamson and Hillemeier 2001a, 2001b). Although salmonids appear to make up a relatively minor component of the diet of seals and sea lions, this does not indicate conclusively that pinniped predation is not significant. Predation may significantly influence salmonid abundance in populations when other prey are absent and physical habitat conditions lead to the concentration of adult and juvenile salmonids in small areas (Cooper and Johnson 1992).

3.4 HATCHERIES

A large body of evidence supports the conclusion that artificial propagation can be detrimental to natural and hatchery salmonid populations (Steward and Bjornn 1990; Hindar et al. 1991; Waples 1991b; Campton 1995; Flagg et al. 2000). Several published studies have found that hatchery stocks are generally less productive in the wild than locally adapted natural stocks, and that transplanted stocks are also less productive than locally adapted natural ones (Leider et al. 1990; Waples 1991b; Meffe 1992; Fleming and Gross 1993; Reisenbichler and Rubin 1999).

Although no direct connection can be made because specific data are lacking, stock transfers from various sources from within and from outside California have been implicated by several authors as a factor that might have contributed to the low diversity and weak population genetic divergence observed in California coho salmon stocks (Brown and Moyle 1991; Bartley et al. 1992; Weitkamp et al. 1995; NMFS 2001). Prolonged hatchery stocking in a particular stream should not be used by itself as documentation of extinction of a distinct wild population. Wild coho salmon stocks can persist in the presence of extensive hatchery stocking.

Hatcheries may have contributed to declines of coho salmon in California, although to what degree is unknown. Currently, their potential to do harm is limited by decreased hatchery production and modern management policy. Hatcheries in California have dramatically reduced their production of coho salmon, limited outplanting, and stopped virtually all stock transfers in recent years. Therefore, current impacts of hatchery fish on remaining natural stocks are significantly less than in the past.

3.5 GENETIC DIVERSITY

An understanding of the existing range and pattern of genetic diversity is essential to effective recovery planning. Section 2.6 reviews the available population genetics information for coho salmon, including patterns of genetic variation that will be useful first approximations for delimiting populations.

Maintenance of genetic diversity is crucially important to the recovery of depleted stocks because genetically diverse taxa:

a. Have a potential for greater overall abundance because different populations can exploit different habitats and resources;

b. Exhibit enhanced long-term stability due to spread risk and redundancy in the face of unpredictable catastrophes (e.g., dramatic rapid fluctuation of climatic or ocean conditions); and

c. Contain a broad range of raw material that allows adaptation and increases the probability of persistence in the face of long-term environmental change (McElhany et al. 2000; Levin and Shiewe 2001).

Numerous literature sources have expressed concerns about loss of genetic diversity in California coho salmon populations (CDFG 2002; Hedgecock et al. 2002; NMFS 2001; Weitkamp et al. 1995; Brown et al. 1994; Brown and Moyle 1991). Coho salmon status reviews (CDFG 2002; NMFS 2001; Weitkamp et al. 1995; Brown et al. 1994; Brown and Moyle 1991) have consistently characterized many California coho salmon populations as small and fragmented, with missing brood years in some places. Some of the threats to genetic diversity that were identified in these reviews are shown in Table 3-1. These threats include small population size effects, inappropriate levels of migration or straying, negative hatchery-natural interactions, and missing brood years. Any recovery actions should take these possible factors into account.

TABLE 3-1: Identified concerns about maintenance of existing genetic diversity and possible causes of reduction of genetic diversity in California coho salmon

FACTOR	RESULTS	EFFECT ON RECOVERY POTENTIAL
Few breeding individuals in each population	• Reduced N_e • Inbreeding depression • Increased rate of genetic drift • Allee Effect	• Loss of within-population genetic diversity • Reduced fitness • Reduced adaptive potential • Reduced evolutionary potential • Inability to find mates • Reduced productivity • High vulnerability to catastrophic events and rapid environmental change
Migration and straying (both more and less than natural rates)	• Impaired metapopulation structure • Inappropriately high migration rate among populations • Outbreeding depression	• Reduced connectivity among populations • Loss of between-population genetic diversity (Homogenization of stocks) • Loss of adaptive complexes • Reduced fitness • Reduced productivity
Hatcheries	Domestication of broodstock Negative natural/hatchery interactions	• Loss of adaptive complexes • Genetic swamping • Reduced fitness of all run components (HO, NO, and HO+NO) • Replacement of well adapted natural runs with poorly adapted hatchery runs • Inappropriate levels of straying • Masking of declines in natural run size
Missing brood years and local extinction	• Reduced N_b, N_e • Loss of potential migrants • Change in population age structure • Incomplete brood-year cycles • Impaired metapopulation structure	• Loss of genetic diversity components • Reduction of potential for gene flow among brood years • Loss of adaptive potential

SOURCES: CDFG 2002; Hedgecock et al. 2002; NMFS 2001; Weitkamp et al. 1995; Brown et al. 1994; Brown and Moyle 1994.

Loss of genetic variation can mean loss of alleles, loss of heterozygosity, or changes in allele frequencies. All of these have the potential to reduce fitness, and can be detrimental to the character and persistence of breeding populations. The risks associated with loss of genetic diversity have been explored in a number of published works including Waples (1991b), Currens and Busack (1995), Busack and Currens (1995), Campton (1995), Grant (1997), and Utter (1998). Loss of variation has been implicated as a factor limiting evolutionary potential (Frankham et al. 1999), and can affect the potential range of response to pathogens (O'Brien and Everman 1989).

Small populations can experience genetic diversity losses through inbreeding and genetic drift. Loss of variation due to inbreeding depression has been reported as a factor that may increase the probability of local extinction (Saccheri et al. 1998). When new populations arise from small numbers of individuals, founder effects can also cause geographically close populations to be different from one another. These effects are countered by migration among populations (straying), mutation, and selection.

Introgressive hybridization can reduce genetic diversity and fitness of genetically different stocks. Straying, artificially high levels of gene flow, and/or inappropriate choice of broodstock for hatchery supplementation may cause locally adapted populations to be more similar to one another with concomitant loss of adaptive complexes, reduced fitness, lowered productivity, and reduction of recovery potential. Even if hybridization effects only become evident in the second generation, long-term recovery may be impeded. It is important to draw a distinction between total genetic diversity and adaptive genetic diversity. The ability of a population to respond to change can be negatively affected by unique but maladaptive genes that nonetheless add to total genetic diversity.

Much of the discussion in the literature regarding loss of diversity has been in the context of impacts associated with hatchery management and practice, and interactions of hatchery fish with natural fish. These impacts include loss of fitness due to domestication and artificial selection that can occur in hatcheries and a variety of other possible negative effects (see CDFG 2002 for a review). In the course of recovery planning, it is important to avoid hatchery impacts on recovering stocks, even as we consider the valid use of hatcheries as a recovery tool.

Many of the causes of genetic diversity loss are related to decreases in population size and associated decreases in effective population size and number of breeders. Because per generation loss of genetic diversity is related to the effective population size of the spawner population, several authors have proposed N_e thresholds that can be used as guidelines in evaluating the severity of potential genetic diversity reductions. The upper portion of Table 3-2 shows some effective population size guidelines from the literature. The lower portion of Table 3-2 shows estimates of the number of breeders per generation and the number of breeders per year that would theoretically be needed to maintain genetic diversity in populations of California coho salmon.

Because salmon populations are usually connected by some small amount of gene flow, and gene flow between populations is a contributor to overall genetic variation, smaller than predicted effective sizes might be sufficient to maintain diversity. Because of this, these guidelines may be more appropriate for evaluating the potential for genetic diversity loss in isolated runs that do not experience immigration from other places. Estimates from two of the studies shown in Table 3-2 (Franklin 1980 and Lande 1995) were based on study of a single species, the fruit fly *Drosophila melanogaster*, and might not be generally applicable to salmon (McElhaney et al. 2000). Therefore, these guidelines should not be used as hard targets for recovery unless they are supported on a case-by-case basis. They can be useful for roughly estimating the potential for diversity loss due to small population size in the absence of specific data. For example, a population with consistent returns of 50 spawners per year might be judged large enough to avoid inbreeding depression, but we would be less confident that a population of this size could maintain adaptive potential over the long term.

TABLE 3-2: Guidelines for number of breeders per generation and number of breeders per year needed to maintain genetic diversity in populations of California coho salmon

Values of N_e or N_b needed to maintain genetic variation:

- Franklin (1980): avoidance of inbreeding depression: $N_e = 50$
- Waples (1990): maintain short term genetic variation [based on p(loss of rare alleles)]: N_b/year = 100
- Franklin (1980) and Lande and Barrowclaw (1987): avoidance of long-term loss of genetic variation: $N_e = 500$
- Lynch (1990), maintain genetic variation in a population: $N_e = 1,000$
- Lande (1995), maintain potentially adaptive genetic variation: $N_e = 5,000$

	0.1	0.1	0.33	0.33
$N_e/N_t = N_e$ MIN	N_b PER GENERATION	N_b PER YEAR	N_b PER GENERATION	N_b PER YEAR
50	500	167	152	51
100	1,000	333	303	101
500	5,000	**1,667**	1,515	505
1,000	10,000	3,333	3,030	1,010
5,000	50,000	**16,667**	15,152	5,051

NOTES: N_e is effective population size, N_b is number of breeders, and N_t is the total census population size. Estimates of N_e/N_t for pacific salmon range from 0.1 to 0.33. An average generation length of three years is used in the calculations.

Values in bold were identified in CDFG (2002) as precautionary targets for maintenance of genetic variation in coho salmon populations.

3.6 LAND USES

A variety of problems and land uses have degraded freshwater and estuarine habitat, created barriers to salmon passage, or degraded coho salmon habitat in other ways. This section describes some of these actions.

3.6.1 FORESTRY ACTIVITIES

Historical forestry practices and some current forestry practices have been shown to impact several freshwater habitat components important to anadromous salmonids in general, and coho salmon specifically. These impacts include increased maximum and average summer water temperatures, decreased winter water temperature, and increased daily temperature fluctuations; increased sedimentation; loss of LWD; decreased DO concentrations; increased instream organic matter; and decreased stream-bank stability (Salo and Cundy 1987; Meehan 1991; Moring et al. 1994; Murphy 1995; Monschke 1996). Table 3-3 lists forestry practices, and describes changes to the landscape and the potential effects on salmonid habitat conditions.

Even when some habitat conditions return to pre-timber-harvest levels, fish populations do not always recover, which may be due to other habitat conditions remaining sub-standard or having been permanently altered (Moring et al. 1994). Logged areas are further affected and aggravated by natural incidents (e.g., blow-downs, landslides) and by human activity subsequent to logging, all of which may result in negative cumulative impacts.

Identifying the relationships between forestry practices and habitat impacts is complicated for several reasons. First, there is a long history of timber harvesting, and some effects, such as sedimentation and slope instability, continue long after harvesting has occurred. These alterations are referred to as "legacy" effects, and recovery may take many decades (Murphy 1995). Legacy effects are a factor along the north coast of California (Monschke 1996). Second, there have been many technological and management changes in timber harvest, and it is difficult to differentiate legacy effects from recent or current effects. Third, the salmonid habitat elements affected by timber harvest are themselves intimately inter-related. The amount and size frequency distribution of LWD, water temperature, near-stream vegetation, sediment transport and deposition, landsliding, stream flow and supply, and turbidity are all linked to one another.

During the approximate 150-year history of timber harvest in coastal northern California, harvest practices have changed dramatically, primarily due to changes in technology and decreasing availability of larger or higher quality logs. Historical harvest and milling were often close to waterways; whereas modern trucks and tractors have enabled more recent harvesting to occur in a wider variety of areas within a watershed. Logs were once primarily transported by river and are now transported by trucks along specially constructed roads. Logs used to be removed from the forest by mules and railroad, and these mechanisms have been replaced by tractors and cabling networks.

Current forestry activities, including forest nonpoint source control programs, have made strides in improving pollution and sediment discharge into streams over historical forestry practices. Forest Practice Rules (FPRs) adopted, in part, for the benefit of anadromous fishes (e.g., FPR 916.9, 936.9, 956.9. Watershed Protection Extension, a.k.a. Threatened and Impaired Watersheds) have been in effect since 2000. Table 3-4 compares the different watercourse protection standards, under pre-2000 FPRs, current California FPRs, and Federal protection (Forest Ecosystem Management Assessment; FEMAT). Although the new rules reduce some site-specific impacts, there has not been sufficient time to determine if there have been benefits to coho salmon.

The Department's conclusion is that historical forestry practices impacted and continue to impact watersheds inhabited by northern California coho salmon, and that current activities

TABLE 3-3: Forestry activities and potential effects to stream environment, salmonid habitat, and salmonid biology

FORESTRY PRACTICE	POTENTIAL EFFECTS TO:		
	STREAM ENVIRONMENT	SALMONID HABITAT	SALMONID BIOLOGY
Timber harvest in the riparian zone	increased incident solar radiation	increased stream temperature, light levels, and primary production	decreased growth efficiency; increased susceptibility to disease; increased food productivity; changes in growth rate and age at smolting
	decreased supply of LWD	decreased cover, storage of gravel and organic debris, and protection from high flows; loss of pool habitat and hydraulic and overall habitat complexity	decreased carrying capacity, spawning gravel, food production, and winter survival; increased susceptibility to predation; loss of species diversity
	increased, short-term input of LWD	increase in number of pools and habitat complexity; creation of debris jams	increased carrying capacity for juveniles and winter survival; barrier to migration and spawning and rearing habitat
	increased influx of slash	increased oxygen demand, organic matter, food, and cover	decreased spawning success; short-term increase in growth
	stream-bank erosion	reduced cover and stream depth	increased carrying capacity for fry; decreased carrying capacity for older juveniles; increased predation
		increased instream fine sediment; reduced food supply	reduced spawning success; slower growth rates for juveniles
Timber harvest on upslope areas	altered stream flow	temporary increase in summer stream flow	temporary increase in survival of juveniles
		increased severity of peak flows during storm season; bedload shifting	increased egg mortality
Timber harvest on upslope areas and road construction and use	increased erosion and mass wasting	increased instream fine sediment; reduced food supply	reduced spawning success, growth and carrying capacity; increased mortality of eggs and alevins; decreased winter hiding space and side-stream habitat
		increased instream coarse sediment	increased or decreased carrying capacity
		increased debris torrents; decreased cover in torrent tracks; increased debris jams	blockage to migration of juveniles and spawning adults; decreased survival in torrent tracks
	increased nutrient runoff	increased primary and secondary production	increased growth rate and summer carrying capacity
	stream crossings	barrier in stream channel; increased sediment input	blockage or restriction to migration; reduced spawning success, carrying capacity and growth; increased winter mortality
Scarification and slash burning	increased nutrient runoff	increased primary and secondary production	increased growth rate and summer carrying capacity
	increased input of fine organic and inorganic sediment	increased sedimentation in spawning gravels and production areas; temporary increase in oxygen demand	decreased spawning success; increased mortality of eggs and alevins

SOURCE: Adapted from Hicks et al. 1991

TABLE 3-4: Comparison of watercourse protection standards

Management Application	California Forest Practice Rules (FPR) Prior To July 1, 2000	FPRS; Protection In Watersheds With Threatened Or Impaired Values	Forest Ecosystem Management Assessment Team (FEMAT) July 1993[a]
CLASS I WATERCOURSE			
Watercourse and Lake Protection Zone (from the hillslope edge of channel zone)	1. to 75' for <30% slopes 2. to 100' for 30-50% 3. to 150' for >50% Widths may be reduced if cable or helicopter system is used	1. 150' minimum 2. No Emergency Notice or Exemption operations allowed within the WLPZ	To top of inner gorge, outer edges of 100-year flood plain, outer edge of riparian vegetation, or to distance equal to height of two site potential trees, or 300 feet, whichever is greatest
WLPZ retention	1. 50% overstory canopy 2. 50% understory canopy 3. Retained overstory canopy must be at least 25% existing overstory conifer 4. Retention of at least 75% surface cover	1. Inner band (0-75'): 85% overstory canopy 2. Outer band (75-150'): 65% overstory canopy 3. Retained overstory canopy must be at least 25% overstory conifer 4. Retention of at least 75% surface cover	Removed from timber base; no timber harvest
Large wood debris retention	Two living conifers/acre, and 50' tall, within 50' of Class I and II watercourses.	The 10 largest trees (dead or alive) per 330' of stream, within 50' of the water-course transition line.	No harvest zones in Riparian Reserves; salvage allowed only if required to attain Aquatic Conservation Strategy (ACS) objectives
Inner gorge special treatment (special zone established where the slope >55%)	None	1. Extends to the first major break-in-slope a distance of 100' or 300' from the water-course transition line, whichever is less 2. Requires use of selection harvesting 3. Even-age management above zone on slope >65% to be reviewed by geologist 4. All slopes exceeding 65% in the zone reviewed by Certified Engineering Geologist	Included in Riparian Reserve; no harvest
CLASS II WATERCOURSE			
WLPZ	1. to 50' for <30% slopes 2. to 75' for slopes 30-50% 3. to 100' for >50% slopes	1. to 50' for <30% slopes 2. to 75' for slopes 30-50% 3. to 100' for >50% slopes 4. No Emergency Notice or Exemption operations allowed within the WLPZ	Permanently flowing non-fish bearing streams – measure from edge of active stream channel; use distance from top of inner gorge, outer edge of 100-year flood plain, outer edges of riparian vegetation, distance of one site potential tree, or 150 feet, whichever is greatest
WLPZ retention	1. 50% total canopy 2. Overstory canopy must be at least 25% existing overstory conifer 3. At least 75% surface cover	1. 50% total canopy 2. Overstory canopy must be at least 25% existing overstory conifer 3. At least 75% surface cover	Removed from timber base, no timber harvest
Large woody debris retention	None	None	No harvest zones in Riparian Reserves; salvage allowed only if required to attain ACS objectives
Inner gorge special treatment	None	None	Included in Riparian Reserve; no harvest
CLASS III WATERCOURSE			
WLPZ	Established at the discretion of the Registered Professional Forester or California Department of Forestry and Fire Protection (CDF)	Established at the discretion of the Registered Professional Forester or CDF	Definable channel and evidence of annual scour or deposition; includes extent of unstable, potentially unstable areas, top of inner gorge, distance equal to site poten-tial tree height or 50', whichever is greatest
WLPZ retention	1. No canopy retention required. 2. 0-30% slope: 25' equipment limitation zone (ELZ) 3. >30% slope: 50' ELZ 4. 50% understory vegetation 5. Trees in channel zone	1. No canopy retention required 2. 0-30% slope: 25' ELZ 3. >30% slope: 50' ELZ 4. 50% understory vegetation 5. Trees in channel zone	No harvest
LWD retention	None	None	No harvest zones in Riparian Reserves; salvage allowed only if required to attain ACS objectives
Inner gorge special treatment	None	None	Included in Riparian Reserve; no harvest

[a] Title 14 of the California Code of Regulations (14 CCR):
§ 895.1 Definitions
§ 898(a) Feasibility Alternatives
§§ 914.8 [934.8, 954.8](g) Tractor Road Watercourse Crossing
§§ 916 [936, 956](e) Intent of Watercourse and Lake Protection
§§ 916.2 [936.2, 956.2](d) Protection of Beneficial Uses of Water and Riparian Functions
§§ 916.9 [936.9, 956.9](y) Protection and Restoration in Watersheds with Threatened or Impaired Values
§§ 916.11 [936.11, 956.11](b) Effectiveness and Implementation Monitoring
§§ 916.12 [936.12, 956.12](f) Section 303(d) Listed Watersheds
§§ 923.3 [943.3, 963.3](h) Watercourse Crossings
§§ 923.9 [943.9, 963.9](g) Roads and Landings in Watersheds with Threatened and Impaired Values

(e.g., road construction, use, and maintenance; activity near streams and on unstable slopes; removal of sources of future LWD), depending on how they are managed, can still affect important habitat elements essential to coho salmon.

3.6.2 WATER DIVERSIONS AND FISH SCREENS

A substantial amount of coho salmon habitat has been lost or degraded as a result of water diversions and groundwater extraction (CDFG 1997, KRBFTF 1991). The nature of diversions varies from major water developments which can alter the entire hydrologic regime in a river, to small domestic diversions which may only have a localized impact during the summer low flow period. In some streams the cumulative effect of multiple small legal diversions may be severe. Illegal diversions are also believed to be a problem in some streams within the range of coho salmon.

Diversions are subject to regulation by the State Water Resources Control Board (SWRCB) through the appropriative water rights process, and by the Department under FGC §1600 *et seq.* (which requires an agreement with the Department for any substantial flow diversion), FGC §2080 *et seq.* (CESA take authorization), and FGC §5937 (which requires sufficient water below a dam to maintain fish in good condition). NOAA Fisheries has authority under ESA to regulate the take of coho salmon at diversions. Hydroelectric diversions, such as those on the Klamath and the Eel rivers are also subject to regulation by the Federal Energy Regulatory Commission (FERC).

In some watersheds, the demand for water has already exceeded the available supply and some water rights have been allocated though court adjudication. These adjudications usually did not consider coho salmon habitat needs at a level that could be considered protective under CESA. The use of wells adjacent to streams is also a significant and growing issue in some parts of the coho salmon range. Extraction of flow from such wells may directly affect the adjacent stream, but is often not subject to the same level of regulatory control as diversion of surface flow. Site specific groundwater studies are required to determine a direct connection between surface flow and groundwater, and these are often very costly and take a significant amount of time to complete.

Losses of coho salmon result from a wide range of conditions related to unscreened water diversions and substandard fish screens. Primary concerns and considerations for fish at diversions that are unscreened or equipped with poorly functioning screens are:

a. Delay of downstream migration and reduced overall survival of downstream migrants;

b. Entrainment of juvenile coho salmon into the diversion;

c. Impingement of juvenile coho salmon on the screen because of high approach velocities or low sweeping velocities;

d. Predator holding areas created by localized hydraulic effects of the fish screen and related facilities;

e. Entrapment of juvenile coho salmon in eddies or other hydraulic anomalies where predation can occur;

f. Elevated predation levels due to concentrating juveniles at diversion structures; and

g. Disruption of normal fish schooling behavior caused by diversion operations, fish screen facilities, or channel modifications.

3.6.3 INSTREAM FLOWS

Land-use practices such as urbanization, agricultural activities, and timber harvest can alter natural hydrologic cycles and impact stream flows, peak flows, flow timing, and flood frequencies. Alteration of the natural hydrological cycle can in turn create significant impacts to coho salmon and their habitat. Impacts to coho salmon can include increasing juvenile and adult mortality by delaying migration because of insufficient flows, stranding fish during rapid flow fluctuations; decreased food supply because of reduced invertebrate drift, and increasing mortality due to higher water temperatures (California Advisory Committee on Salmon and Steelhead Trout [CACSST] 1988; CDFG 1991; Berggren and Filardo 1993; Reynolds et al. 1993; Chapman et al. 1994; Cramer et al. 1995; NMFS 1996). In addition to these factors, alteration of the natural hydrograph can increase deposition of fine sediments in spawning gravels, decrease recruitment of LWD and spawning gravels; it may also lead to encroachment of riparian and non-endemic vegetation into spawning and rearing areas (e.g., on the Trinity River) (CACSST 1988; Forest Ecosystem Management Assessment Team 1993; Botkin et al. 1995; NMFS 1996).

Many of the watersheds where coho salmon are present have been developed and flows have been regulated and significantly reduced compared to natural flows. Base flow necessary for coho salmon rearing during the typical May to November low flow period may be severely limited due to interactions between watershed area, climate, geology, and land use. For example, an Instream Flow Incremental Methodology study of lower Scott Creek, Santa Cruz County (Snider et al. 1995) found that optimum habitat conditions for juvenile steelhead and coho salmon in Scott Creek are provided at 20 cfs, and only half of the maximum habitat remains at 5 to 6 cfs. However, median flows in Scott Creek in August, September and October are 2 cfs or less (roughly 16% of maximum habitat).

A common problem in minimizing the direct and cumulative effects of diversions on instream flow is the lack of detailed data regarding minimum instream flow needs for coho salmon in a given stream. Some of the major water developments in the range of coho salmon are, or have been, the subject of extensive studies and programs aimed at evaluating and reducing the impact of those projects on coho salmon and other species. However, studies on the effects of smaller diversions are generally lacking, as are studies of overall instream flow needs in watersheds in the range of coho salmon. The owners of smaller diversions frequently lack the resources to conduct the appropriate studies to evaluate instream issues.

For small diversions (≤ 3 cfs and ≤ 200 acre-feet) in Mendocino, Sonoma, Marin and Napa counties, the Department and NOAA Fisheries have proposed draft guidelines that may serve as conditions for protection of salmonid habitat in lieu of results from site-specific studies (CDFG/NOAA Fisheries 2002), and in some cases these conditions may require substantial alteration of existing diversion and storage patterns. Current resource agency staffing and funding is generally inadequate to conduct watershed-level instream flow studies and to take the effective regulatory actions to restore flow for coho salmon habitat where it is an issue. The lack of adequate enforcement staff and problems coordinating efforts by regulatory agencies also makes consistent control of illegal diversions difficult.

3.6.4 ARTIFICIAL BARRIERS

Artificial structures on streams fragment aquatic ecosystems by blocking or impeding migration and altering nutrient cycling patterns, streamflows, sediment transport, channel morphology, and stream-corridor species composition. This reduces available habitat, changes habitat conditions for anadromous salmonids, and reduces native biodiversity. Instream structures have the potential to, depending on conditions, either entirely or partially block fish from accessing upstream reaches and block critical habitat necessary for survival. Barriers can be formed by:

a. Road crossings (e.g., bridges, culverts, and low-water fords);
b. Dams;
c. Flood-control structures (e.g., concrete channels);
d. Erosion control structures (riprap and energy dissipaters);
e. Canal and pipeline crossings;
f. Pits from gravel mining; and
g. Conditions that sever surface or subsurface hydrologic connections between the stream channel and adjacent wetlands.

Even if stream barriers are eventually negotiated by fish, the extra energy expended may result in their death prior to spawning or in reductions in viability of eggs and offspring. Barriers that increase the time required for migration can limit the distance adult fish are able to travel upstream before spawning, resulting in the crowding of redds in lower stream reaches and under-utilization of upstream habitat. Migrating adults and juveniles concentrated below barriers with impassable crossings are also more vulnerable to predation and illegal harvest.

Hydropower and water storage projects alter the hydrograph of downstream river reaches and can affect migration cues and physical passage conditions. Dams often block access to areas used historically by coho salmon. Weitkamp et al. (1995) identified nine dams in California that currently have no fish passage facilities to allow coho salmon access to former spawning and rearing habitats. Blocked habitat constitutes approximately 9 to 11% of the historical range of each coho salmon ESU. Five major dams within the California portion of the SONCC Coho ESU (Table 3-5) and four major dams within the CCC Coho ESU (Table 3-6) block access to historical spawning and rearing areas of coho salmon. In addition to these, there are five smaller impoundments on the mainstem Russian River, and approximately five hundred licensed or permitted dams on its tributaries (SEC 1996).

3.6.5 GRAVEL EXTRACTION

Gravel extraction (the removal of sediment from the active channel) has various impacts on salmonid habitat by interrupting sediment transport and often causing channel incision and degradation (Kondolf 1993). The impacts that can result from gravel extraction include: direct mortality; loss of spawning habitat; noise disturbance; disruption of adult and juvenile migration and holding patterns; stranding of adults and juveniles; increases in water temperature and turbidity; degradation of juvenile rearing habitat; destruction or sedimentation of redds; increased channel instability and loss of natural channel geometry; bed coarsening; lowering of local groundwater level; and loss of LWD and riparian vegetation (Humboldt County Public Works 1992; Kondolf 1993; Jager 1994; Halligan 1997). Terrace mining (the removal of aggregate from pits isolated from the active channel) may have similar impacts on salmonids if a flood causes the channel to move into the gravel pits.

Instream gravel extraction has had direct, indirect, and cumulative impacts on salmonids in the recent past. Current (post-1995) mining, monitoring, and reporting standards developed by the Department and the mining industry, which were incorporated into County Conditional Use Permits, reclamation plans required by the Surface Mining and Reclamation Act, and U.S. Army Corps of Engineer (USACE) Letters of Permission, seek to avoid and minimize current impacts. Many rivers continue to suffer the effects of years of channel degradation from the millions of tons of aggregate removed from the systems over time (Collins and Dune 1990).

TABLE 3-5: Major dams within the California portion of the SONCC Coho ESU that block coho salmon from accessing historical spawning and rearing habitat

NAME OF DAM	LOCATION	UPSTREAM HABITAT BLOCKED	PERCENT OF ENTIRE BASIN
Scott Dam	Eel River, approximately 169 miles upstream from the Pacific Ocean, forming Lake Pillsbury in Lake County	36 miles	8% (Eel River Basin)
Matthews Dam	Mad River, approximately 79 miles upstream from the Pacific Ocean, forming Ruth Lake in Trinity County	2 miles	13% (Mad River Basin)
Lewiston Dam	Trinity River (tributary to the lower Klamath River), approximately 112 miles upstream from the Pacific Ocean, forming Lewiston Reservoir in Trinity County	109 miles	24%(Trinity Basin) 9% (Klamath Basin
Dwinnell Dam	Shasta River (tributary to the upper Klamath River), approximately 214 miles upstream from the Pacific Ocean, forming Dwinnell Reservoir in Siskiyou County	17 miles	17% (Shasta Basin) 2% (Klamath basin)
Iron Gate Dam	Klamath River, approximately 190 miles upstream from the Pacific Ocean, forming Iron Gate Reservoir in Siskiyou County	30 miles	8% (Klamath basin)

TABLE 3-6: Major dams within the CCC Coho ESU that block coho salmon from accessing historical spawning and rearing habitat

NAME OF DAM	LOCATION	UPSTREAM HABITAT BLOCKED	PERCENT OF ENTIRE BASIN
Peters Dam	Lagunitas Creek, approximately 14 miles upstream from the Pacific Ocean, forming Kent Lake in Marin County	8 miles	6%
Nicasio Dam	Nicasio Creek, (tributary to Lagunitas Creek), approximately 8 miles upstream from the Pacific Ocean, forming Nicasio Reservoir in Marin County	5 miles	10%
Warm Springs Dam	Dry Creek (tributary to the Russian River), approximately 45 miles upstream from the Pacific Ocean, forming Sonoma Lake in Sonoma County	50 miles	9%
Coyote Dam	Russian River, approximately 95 miles upstream from the Pacific Ocean, forming Lake Mendocino in Mendocino County	36 miles	7%
Newell Creek Dam	San Lorenzo River, approximately 14 miles upstream from the Pacific Ocean, forming Loch Lomond Reservoir in Santa Cruz County	6 miles	10%

3.6.6 SUCTION DREDGING

Suction-dredge placer miners extract gold from the river gravels by sucking the gold- bearing gravels through a nozzle (typically 6 to 8 inches in diameter) into floating dredges, pumping the gravel and water mixture across a settling table where the gold concentrates by gravity, and then discharging the gravel and water back into the river. Both the pump and the sluice box are usually mounted on a floating platform, often positioned over the work area by ropes or cables secured to trees or rocks. The portion of stream bottom dredged ranges from a few small excavations to the entire wetted area in a section of the stream. Larger suction dredges have the capacity to process as much as several cubic yards of gravel from the river bottom at one time. An annual permit from the Department (Title 14 California Code of Regulations [CCR], §228) and, in some circumstances, a Lake and Streambed Alteration Agreement (FGC §1600) is required to engage in this activity.

Dredging activities in freshwater environments can have a variety of direct impacts on the environment, including impacts on aquatic and riparian organisms (Griffith and Andrews 1981;

Thomas 1985; Harvey 1986) and channel stability. Impacts can also result from the potential release of hazardous materials such as mercury into aquatic and terrestrial environments. However, there are no studies that document such dredging-related impacts on coho salmon or their habitat within the range of coho salmon. The restrictions currently imposed by regulations on this activity are designed to eliminate the potential for impacts to coho salmon by restricting suction dredging actions to locations and times when such activities should not impact the species.

3.6.7 STREAMBED ALTERATION

Streambed alteration activities such as construction of roads, navigational improvements, dams, bank stabilization structures, and channels can result in a loss of habitat complexity (Bisson et al. 1987). Effects include decreases in the range and variability of stream flow velocities and depths, and reductions in the amount of large wood, boulders, and other stream structures. Construction activities in the stream channel can cause excess sediment to fill pools. Channelization that includes paving the channel bottom, or changing the length or sinuosity of the channel, permanently alters the substrate, eliminating macroinvertebrate habitat, instream vegetation, and the gravel substrate necessary for spawning.

3.6.8 WATER QUALITY

Water pollution originates from point sources and non-point sources as listed in Table 3-7, and includes sediment, nutrients, biocides, metals, and metalloids. It is difficult to correlate specific pollutants with specific and direct effects on coho salmon. Mixed compounds may have different effects on the biological community of a stream than would an accumulation of the same compounds considered separately. In addition, effects vary with habitat alteration, temperature, and the concentration of dissolved materials in the surface waters (Brown and Sadler 1989). Water quality within coho salmon range is known to be affected by industrial discharges, agricultural discharges, silvicultural discharges, mineral mining wastes, municipal wastewater discharge, road surface discharge, and urban stormwater discharge.

Under CWA § 303(d), states, territories and authorized tribes are required to develop lists of impaired waters that do not meet water quality standards, even after those responsible for point sources of pollution have installed the minimum required levels of pollution control technology. In addition, the law requires that they establish priority rankings for waters on the lists and develop action plans, including total maximum daily load (TMDL) plans to improve water quality. Within the California range of coho salmon, there are 74 water bodies that are on the § 303(d) list of impaired water bodies (Table 3-7).

TMDLs in California are developed either by Regional Water Quality Control Boards (RWQCB) or by the U.S. Environmental Protection Agency (EPA). TMDLs developed by RWQCBs are designed as Basin Plan amendments and must include implementation provisions. TMDLs developed by EPA typically contain the total load and load allocations required by § 303(d), but do not contain comprehensive implementation provisions. It is the responsibility of the RWQCBs to develop implementation programs for TMDLs established by the EPA and during that process, it has often been necessary for the RWQCBs to reevaluate, and sometimes change, the EPA requirements.

3.6.9 AGRICULTURAL IMPACTS

Historic, and some current, agricultural practices impact freshwater habitat components important to coho salmon. While current agricultural activities and programs have made strides in improving pollution and sediment discharge into streams and in habitat restoration,

TABLE 3-7: Clean Water Act §303(d) list of impaired water bodies within the range of coho salmon in California (as approved by USEPA, July 2003)

NAME	EST. SIZE/LENGTH OF AFFECTED AREA	POLLUTANT/STRESSOR	SOURCE OF POLLUTION[a]
SAN FRANCISCO BAY			
Carquinez Strait	5,657 acres	Chlordane; DDT; PCBs; PCBs (dioxin-like); Diazinon; Dieldrin; Dioxin compounds; Exotic species; Mercury; Furan compounds; Selenium	5, 6, 20, 26, 27, 28, 36, 48
Richardson Bay	2,439 acres	Chlordane; DDT; PCBs; PCBs (dioxin-like); Dieldrin; Dioxin compounds; Exotic species; Mercury; Furan compounds; High coliform counts	5, 6, 7, 26, 27, 28, 36, 38, 45, 48
San Francisco Bay[b]	171,954 acres	Agriculture; Chlordane; DDT; Diazinon; Dieldrin; Dioxin compounds; Exotic species; Furan compounds; Mercury; Nickel; PCBs; PCBs (dioxin-like); Selenium	1, 5, 6, 20, 26, 27, 28, 36, 48
San Pablo Bay	68,349 acres	Agriculture; Chlordane; DDT; Diazinon; Dieldrin; Dioxin compounds; Exotic species; Furan compounds; Mercury; Nickel; PCBs; PCBs (dioxin-like); Selenium	1, 5, 6, 20, 26, 27, 28, 36, 48
Suisun Bay	27,498 acres	Chlordane; DDT; Diazinon; Dieldrin; Dioxin compounds; Exotic species; Furan compounds; Mercury; Nickel; PCBs; PCBs (dioxin-like); Selenium	5, 6, 20, 27, 28, 36, 48
Suisun Marsh Wetlands	66,339 acres	Metals; Nutrients; Organic enrichment/low dissolved oxygen; Salinity/TDS/chlorides	1, 45, 15
Suisun Slough	1,124 acres	Diazinon	45
Tomales Bay	8,545 acres	Mercury; Nutrients; Pathogens; Sedimentation/siltation	1, 4b, 25, 38, 44
Alameda Creek	51 miles	Diazinon	45
Arroyo Corte Madera Del Presidio (Mill Creek)	4 miles	Diazinon	45
Corte Madera Creek	4.1 miles	Diazinon	45
San Antonio Creek	18 miles	Diazinon	45
San Pablo Creek	9.9 miles	Diazinon	45
Walker Creek	16 miles	Mercury; Nutrients; Sedimentation/siltation	1, 25, 42
Walnut Creek	9 miles	Diazinon	45
NORTH COAST			
Albion River	77 miles	Sediment/siltation	23, 28, 39
Big River	225 miles	Sediment/siltation; Temperature	12, 13, 17, 22, 23, 28, 32, 37, 39, 41
Eel River[b]	4,637 miles	Sediment/siltation; Temperature	4b, 9, 10, 12, 13, 15, 16, 17, 19, 22, 23, 28, 32, 33, 34, 35, 36, 39, 41, 43, 44
Elk River	88 miles	Sediment/siltation; Temperature	13, 16, 23, 27, 28, 32, 33, 34, 39, 41

continued

TABLE 3-7: Clean Water Act §303(d) list of impaired water bodies within the range of coho salmon in California (as approved by USEPA, July 2003) (continued)

NAME	EST. SIZE/LENGTH OF AFFECTED AREA	POLLUTANT/STRESSOR	SOURCE OF POLLUTION[a]
Estero Americano	199 acres	Nutrients; Sediment/siltation	13, 19, 24, 28, 32, 35, 41, 43
Freshwater Creek	84 miles	Sediment/siltation	13, 16, 23, 27, 28, 32, 33, 34, 39, 41
Garcia River	154 miles	Temperature	17, 28, 32, 41
Gualala River	455 miles	Sediment/siltation; Temperature	16, 33, 34, 39,
Humboldt Bay	16,075 acres	PCBs	49
Klamath River[b]	4,759 miles	Nutrients; Temperature; Organic enrichment/low dissolved oxygen	1, 2, 3, 4a, 4b, 9, 11, 12, 15, 17, 19, 20, 21, 26, 27, 28, 32, 35, 40, 43, 44, 46, 49, 50, 51
Mad River	654 miles	Sediment/siltation; Temperature; Turbidity	15, 17, 28, 32, 36, 39, 44, 49
Mattole River	503 miles	Sediment/siltation; Temperature	13, 17, 19, 27, 28, 32, 35, 37, 39, 40, 41, 43
Navarro River Delta	48 acres	Sediment/siltation	13
Navarro River	415 miles	Sediment/siltation; Temperature	1, 3, 8, 9, 10, 12, 13, 15, 16, 17, 18, 21, 22, 23, 28, 32, 33, 34, 35, 36, 39, 40, 41, 46
Noyo River	144 miles	Sediment/siltation	28, 39
Redwood Creek	332 miles	Sediment/siltation; Temperature	10, 13, 16, 23, 27, 28, 32, 33, 34, 35, 39, 41
Russian River[b]	1,711 miles	Sediment/siltation; Temperature; Pathogens	1, 4a, 4b, 8, 9, 10, 11, 12, 13, 15, 17, 19, 21, 22, 27, 28, 32, 35, 39, 41, 43, 44, 52, 53
Scott River	902 miles	Sediment/siltation; Temperature	3, 12, 15, 17, 21, 27, 28, 32, 35, 36, 39, 43, 46, 54
Shasta River	630 miles	Organic enrichment/low dissolved oxygen; Temperature	2, 4a, 11, 12, 15, 17, 19, 32, 55
Ten Mile River	162 miles	Sediment/siltation; Temperature	17, 23, 28, 32, 33, 34, 39, 41
Trinity River[b]	3,410 miles	Sediment/siltation; Temperature	9, 11, 12, 13, 15, 16, 17, 19, 23, 25, 27, 28, 32, 33, 34, 35, 36, 39, 41, 42, 44, 46
Van Duzen River	585 miles	Sediment/siltation	9, 10, 13, 16, 17, 23, 27, 32, 33, 34, 35, 39, 41, 43,
CENTRAL COAST			
Aptos Creek	8.4 miles	Sediment/siltation; Pathogens	9, 22, 45
San Lorenzo River	27 miles	Nutrients; Pathogens; Sedimentation/siltation	10, 28, 38, 39, 45
San Lorenzo River Lagoon	66 acres	Pathogens	27, 45
Soquel Lagoon	1.2 acres	Nutrients; Pathogens; Sedimentation/siltation	10, 27, 28, 28, 45
Waddell Creek, East Branch	3.5 miles	Nutrients	26

[a]
1 Agriculture
2 Agriculture-irrigation tailwater
3 Agricultural return flows
4a Agriculture-storm runoff
4b Animal operations
5 Atmospheric deposition
6 Ballast water
7 Boat discharges/vessel wastes
8 Bridge construction
9 Channel modification, channelization
10 Construction/land development
11 Dam construction and operation
12 Drainage/filling of wetlands
13 Erosion/siltation
14 Filling of wetlands
15 Flow regulation/modification
16 Harvesting
17 Habitat modification
18 Highway/road construction
19 Hydromodification
20 Industrial point source
21 Irrigated crop production
22 Land development
23 Logging road construction/maintenance
24 Manure lagoons
25 Mine tailings
26 Municipal point source
27 Natural sources
28 Nonpoint source
29 Other urban runoff
30 Pasture land
31 Range land
32 Removal of riparian vegetation
33 Residue management
34 Restoration
35 Riparian grazing
36 Resource extraction
37 Road construction
38 Septage disposal
39 Silviculture
40 Specialty crop production
41 Stream-bank modification/destabilization
42 Surface mining
43 Upland grazing
44 Upstream impoundment
45 Urban runoff/storm sewers
46 Water diversions
47 Water (groundwater), domestic use
48 Source unknown
49 Out-of-state source
50 Wastewater land disposal
51 Combined sewer overflow
52 Geothermal development
53 Surface runoff
54 Mill tailings
55 Dairies

[b] Contains combined information for two or more separate river forks or subsystems.

some activities can affect coho salmon habitat. Agricultural practices affect aquatic and riparian areas through non-point source pollution, since these areas eventually receive sediments, fertilizers, pesticides, and wastes from associated agricultural lands.

While it has been reported that sediment delivery to streams in the form of non-point source pollution is caused mainly by roads (Lewis et al. 2001), sediment is the most common type of non-point source pollution from agricultural lands (Knutson and Naef 1997). According to Terrell and Perfetti (1989), erosion of crop lands accounts for 40 to 50% of the sediment in United States waterways. Storm runoff erodes the topsoil from open agricultural areas, and irrigation water from standard agricultural practices also carries significant amounts of sediment to the stream environment. According to Terrell and Perfetti (1989), two types of irrigation systems, sheet flow and rill, cause the greatest amount of surface erosion, while drip irrigation and piped laterals produce the least. Irrigation often uses water that is drawn from a stream, lake, pond, or the ground. Pumping from the water table reduces its level, decreasing flow to and in the river. The ability of a stream to diminish the effects of irrigation waste discharged decreases proportionally with reductions in stream flow.

Small coastal streams often rely on springs to maintain flows through the summer months, but the flow of these springs is often diminished by pumping from the aquifers that supply them. Many streams that once flowed year-round no longer do so, because of recent increases in hillside agricultural land conversion and reduction in local groundwater levels. The conversion of uplands from forest or grasslands to agriculture increases erosion and ground water use (CDFG 2001). In February 2000, Sonoma County adopted a vineyard ordinance to control sedimentation caused by vineyard erosion (Merenlender et al. 2000). The ordinance identifies three levels of vineyards and seven types of highly erosive soils, imposing corresponding requirements (CDFG 2001).

Animal wastes carried by runoff can contaminate water sources through the addition of oxygen-depleting organic matter (Knutson and Naef 1997). Runoff from concentrated fecal sources can change water quality, causing lethal conditions for fish. As the biochemical oxygen demand increases, dissolved oxygen decreases, and ammonia is released, causing additional changes that are stressful to fish.

Grazing can affect riparian characteristics and associated aquatic systems, such as vegetative cover, soil stability, bank and channel structure, instream structure, and water quality and quantity. Behnke and Zarn (1976) and Armour et al. (1991) indicate that overgrazing is one of the major contributing factors in the decline of Pacific Northwest salmon. Trampling may compact soils, decreasing water infiltration and increasing runoff. However, light trampling can break up surface soils that have become impervious, and allow for greater water absorption; but this also makes the soil more susceptible to erosion (Spence et al. 1996). George et.al. (2002) found that cattle trails in California produced 40 times more sediment than adjacent vegetated soil surfaces. Possible grazing impacts also include increased nutrient inputs from deposition or release of animal waste in watercourses. According to Knutson and Naef (1997), some of the ways that poor grazing practices can impact fish and wildlife include:

a. Destruction of riparian vegetation;
b. Reduction or elimination of regeneration of woody vegetation;
c. Changes to plant species composition in favor of non-riparian species;
d. Loss of protective vegetation and associated bank stability and structure;
e. Soil compaction;
f. Increase of stream-bank erosion, causing stream channel widening, shallowing, trenching, or braiding;

g. Reduction in the ability of riparian areas to trap and filter sediments and pollutants;
h. Increase in stream temperatures due to loss of cover;
i. Increase in the magnitudes of high and low flows;
j. Lowering of the water table, and associated loss of riparian vegetation; and
k. Loss of nutrient inputs, especially invertebrate food sources, to stream.

To address potential environmental impacts of agricultural operations, several programs have been developed. These programs assist landowners in developing best management practices for their respective crops and land use. Some of the programs developed include the Code of Sustainable Winegrowing Practices, the Rangeland Water Quality Shortcourse, and the Dairy Quality Assurance Program.

3.6.10 URBANIZATION AND URBAN IMPACTS

Within the California range of coho salmon, urban and suburban development occupy 924 square miles or 9.3% of the land base (CDFG unpublished data). Cities and towns with large developed areas within the range of California coho salmon include, from north to south, Crescent City, Arcata, Eureka, Fortuna, Willits, Ukiah, Healdsburg, Sebastopol, Santa Rosa, Petaluma, Sonoma, Napa, Novato, San Francisco Bay Area, and Santa Cruz.

Urbanization not only affects habitat in obvious ways – for example, direct loss of habitat, channelization of streams, degradation of water quality, and dewatering of streams – but it can also affect habitat in less obvious ways by altering and disrupting ecosystem processes that can have unintended impacts to aquatic ecosystems through increased flooding, channel erosion, landslides, and aquatic habitat destruction (Booth 1991).

It is impossible to separate the overlapping and interrelated impacts of urbanization; however, the following broad categories are used to frame the following discussion.

3.6.10.1 Alteration of Natural Vegetation

Urbanization can cause severe and permanent alteration of the natural vegetation by its removal or conversion to lawns and ornamental plants. In upland areas this can contribute to erosion and altered drainage, often reducing infiltration and increasing surface runoff. However, impacts are particularly severe in riparian corridors where vegetation is commonly removed to increase the visibility of and access to streams and to allow the installation of landscaping and structures very near the tops of stream banks. Loss of riparian vegetation reduces inputs of nutrients, recruitment of LWD, and stream-bank stability (Booth 1991; Spence et al.1996). It also leads to an increase in stream temperature by removing much of the overhead canopy (Booth 1991).

3.6.10.2 Disrupted Hydrological Processes and Reduced Stream Complexity

Construction and landscaping near streams is often followed by the installation of retaining walls and other hard structures intended to protect or enlarge developed areas. This results in severely constricted streams with disabled or altered hydrological and riparian processes. Furthermore, in developed areas, much of the surface soil is covered by impervious surfaces (buildings, parking lots, roads) which increase peak flows and change channel characteristics. These changes produce measurable effects in the hydrologic response of a drainage basin, particularly an increase in maximum discharge associated with floods and an increase in frequency of flooding (Klein 1979; Booth 1991).

To facilitate the movement of storm runoff, stream channels are often straightened and the banks denuded of vegetation and covered with revetment. In areas where revetments are not installed, channels become less stable because of the increase in bedload transport that accompanies increased water volumes and velocities (Bryan 1972). Both situations lead to loss of bank and instream habitat complexity and an increased uniformity of the channel and bed. The lack of LWD inputs exacerbates channel simplification, causing increased bed scour and fill. Many degraded urban streams have uniform beds with few pools or riffles, exposed near-vertical banks downcut by several feet, chronic high sediment loads due to increased bank erosion, deficient woody debris, and severely reduced aquatic organisms compared to nearby undeveloped streams (Booth 1991). Urbanized streams take on a clean, washed-out look as channel complexity is lost (Lucchetti and Fuerstenberg 1993, as cited in Spence et al. 1996). These highly modified channels generally provide poor habitat for fish (Spence et al. 1996).

Not only do impervious areas increase peak flow, they also block infiltration into the soil (Klein 1979; Booth 1991), thus decreasing the ability of the basin to store precipitation and reducing summer base flows (Spence et al. 1996). These changes occur primarily because of increases in the impervious surface area and the replacement of complex, natural drainage channels with a network of storm pipes and drainage ditches (Lucchetti and Fuerstenberg 1993, as cited in Spence et al. 1996). Clearing of vegetation, compaction of soil, installation of roads and other impervious surfaces, grading of depressions, and direct interception of subsurface flows by drains can lead to irreversible effects to drainage basin hydrology (Booth 1991).

3.6.10.3 Degradation of Soil Function

Significant soil disturbance occurs during the construction phase of urban development, which leads to increased sediment loads (Klein 1979). After construction, buildings, concrete, and asphalt cover much of the surface soil and areas that remain exposed are often altered by irrigation and fertilization necessary to support domestic vegetation. This likely diminishes the ecological functions of the soil (Spence et. al., 1996).

3.6.10.4 Impaired Water Quality

Wanielista (1978, as cited in Spence et al. 1996) identifies numerous types of urban non-point source pollution, including heavy metals, pesticides, bacteria, organics (oil and grease), dirt, and nutrients. In urbanized streams, the type and quantity of nutrients can change significantly: such as LWD and leafy detritus are replaced in importance by nutrient loading from sewage and other sources (Spence et al. 1996). Novitzki (1973, as cited in Spence et al. 1996) reports that high nutrient levels from a small Wisconsin sewage treatment plant effluent significantly degraded brook trout *(Salvelinus fontinalis)* habitat.

The principal effect of nutrients upon a stream is the stimulation of algae and other aquatic plant growth (Klein 1979). As plant growth increases, night-time dissolved oxygen levels can be become critically low due to continuing plant respiration coupled with the cessation of photosynthesis. Novitzki (1973, as cited in Spence et al. 1996) notes that the nutrients greatly stimulated primary and secondary production, which resulted in a high oxygen demand that created critically low dissolved oxygen levels that ultimately resulted in fish kills. Omernik (1977, as cited in Klein 1979) found that total nitrogen exports from urban areas were second only to intensively farmed watersheds.

Water quality impacts from stormwater runoff are well documented. Bryan (1972) found that pesticide concentration in runoff was three times as high as that from a rural area. In industrial areas, runoff may include heavy metals, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), high pH concrete dust, and other toxic chemicals (Birch et al. 1992, as cited in Spence et al. 1996). Non-point source pollution from agricultural and urban land uses has caused long-term, cumulative harm to stream ecosystems (Jones and Clark 1987;

McDonnell and Pickett 1990; Richards et al. 1996, all cited in Wang et al. 1997). Contaminants associated with sediments can have significant impacts on water quality (Spence et al. 1996).

Several habitat changes caused by urbanization can affect the natural stream temperature regimen (Klein 1979). The effect of reduced shade on maximum temperatures has been well documented. Reduction in shading results from alteration of banks and loss of riparian vegetation. Increase in channel width increases the area of unshaded stream surface area, reduces water depths, and further contributes to heat loss or gain, increasing diurnal temperature fluctuations (Klein 1979). Stream temperatures in urban areas may also be indirectly affected by changes in hydrology, channel morphology, and microclimate (Spence et al. 1996). Lower summer base flows resulting from reduced infiltration can also contribute to higher water temperatures.

3.6.10.5 Barriers to Passage

Urban development is characterized by high road densities and the resulting bridges, culverts, and other structures that constrain channels and impede fish migration (Spence et al. 1996). Areas of high temperature and poor water quality can also present barriers to passage.

3.6.10.6 Degraded Biological Diversity and Habitat Suitability

The structure of the biological community and abundance and diversity of aquatic organisms are greatly altered by urban impacts on channel characteristics and water quality. Wang et al. (1997) found that high urban land use was strongly associated with poor biotic integrity and was associated with poor habitat quality.

Fish populations are also adversely affected by urbanization. Limburg and Schmidt (1990, as cited in Spence et al. 1996) found a measurable decrease in spawning success of anadromous species in Hudson River tributaries that had 15% or more of the watershed in urban development. Wang et al. (2003) found a strong negative relation between urban land cover in the watershed and the quality of fish assemblages in coldwater streams in Wisconsin and Minnesota. In a study of urbanized Puget Sound streams, Lucchetti and Fuerstenberg (1993, as cited in Spence et al. 1996) found that coho salmon appeared to be more sensitive than cutthroat trout *(O. clarki)* to habitat alteration, increased nutrient loading, and degradation of the intergravel environment. They found that as impervious surfaces increased, coho salmon abundance declined, and concluded that coho salmon are of particular concern in urbanized areas because of their specific habitat needs (smaller streams, relatively low velocity microhabitats, and large pools). Other recent studies have documented that pollution associated with urban areas is causing impacts to juvenile Chinook salmon, including suppressed immune response due to bioaccumulation of PCBs and PAHs, increased mortality associated with disease, and suppressed growth (Spence et al. 1996).

The key to protecting and restoring urban streams appears to be reducing imperviousness and protecting channel integrity and riparian vegetation. Klein (1979) found that stream quality impairment is first observed when watershed imperviousness reaches 15% of the total watershed, and becomes severe at 30%. He recommends that for more sensitive stream ecosystems, such as those containing self-sustaining trout populations, watershed imperviousness should not exceed 10%. Wang et al. (2003) found that even low levels of urban development can damage cold-water stream systems, and State that strategies that protect the riparian area and minimize imperviousness may reduce the damage. Booth (1991) states that the strategy for minimizing or avoiding impacts associated with urban development is to reduce the amount of runoff and minimize landscape disturbance.

3.6.11 FISHING

Retention of coho salmon has been prohibited in ocean commercial fisheries south of Cape Falcon, Oregon since the beginning of the 1993 season. From Cape Falcon to Horse Mountain, California, coho salmon retention has been prohibited in ocean recreational fisheries since the 1994 season, and starting May 1995, the prohibition was extended to include sport fisheries south of Horse Mountain. California's inland waters have been explicitly closed by regulation to coho salmon retention since 1998. Coho salmon are taken incidentally in commercial and recreational fisheries directed toward other salmon species. If large enough numbers are hooked, substantial mortality can be incurred.

The Klamath Basin's Native American tribes (Yurok, Hoopa Valley, and Karuk) currently operate the only existing sanctioned coho salmon fishery. Both the Yurok and Hoopa Valley tribes have Federally recognized fishery rights in the basin, and Tribal subsistence, ceremonial, and minor commercial fisheries operate under the regulatory authority of each tribe. Each tribe determines the extent of fishing opportunities that will be provided its Tribal members based on estimates of preseason abundance. Data for this review are only available for the Yurok Tribe's harvest for subsistence and ceremonial fisheries within the Tribe's reservation on the lower Klamath River (Weitchpec downstream to the ocean); these fisheries have been monitored since 1992. Harvest has ranged from 27 to 1,168 fish caught annually, and based on estimates of upstream escapement (in-river spawners and hatchery returns), is thought to amount to an average harvest rate of 4.4% for the period (D. Hillemeier pers. comm.).

3.6.12 ILLEGAL HARVEST

Illegal harvest can have an impact on populations of fishes in certain areas, although this depends on intensity, frequency and species of fish taken. The Wildlife Protection staff of the Department indicates that illegal harvest of both juvenile and adult coho salmon does occur, although most of the illegal take is due to anglers mistaking coho salmon for another species. Most of the violations involving the illegal take of adult coho salmon occur in the offshore sport fishery. Illegal harvest in inland waters is mostly opportunistic, meaning poachers will spear, net, gaff or snag whatever salmonid happens to be in the stream (T. Belt pers. comm.).